Curtis (Ed)

THE PROTOPLASM THEORY:

AN INTRODUCTORY LECTURE

DELIVERED AT THE OPENING OF THE WINTER SESSION OF THE COLLEGE OF PHYSICIANS AND SURGEONS, NEW YORK, OCTOBER 1, 1873.

BY

EDWARD CURTIS, A.M., M.D.,

PROFESSOR OF MATERIA MEDICA AND THERAPEUTICS.

Published by the Medical Class

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CHAS. E. WILBOUR, PRINTER AND BOOKBINDER,
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COLLEGE OF PHYSICIANS AND SURGEONS,
NEW YORK, *October* 18, 1873.

DR. EDWARD CURTIS:

DEAR SIR:—We take great pleasure in acquainting you with the following resolution, which was passed at a meeting of the medical class of the present Winter Session:

"That a committee of three be appointed to carry out the necessary arrangements for the publication of the introductory lecture of Prof. Edward Curtis, delivered on the evening of October 1, 1873."

We would not consider the duty which this resolution imposes upon us, as representatives of the class, fully performed, if, while we most respectfully beg that your manuscript be placed in our hands, we did not at the same time convey to you the satisfaction with which the resolution was received and the generosity with which it was sustained by the united medical class.

We remain, most respectfully yours,

A. P. ZENANSKY,
L. L. DANFORTH,
J. E. STILLWELL,
Committee.

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27 WASHINGTON PLACE, NEW YORK,
October 20, 1873.

Messrs. A. P. ZENANSKY, L. L. DANFORTH, J. E. STILLWELL:

GENTLEMEN:—It will give me great pleasure to accede to the flattering request of the medical class to publish my introductory address, and the manuscript is at your disposal for the purpose.

Very truly yours,
EDWARD CURTIS.

THE PROTOPLASM THEORY.

Gentlemen:—The pursuit upon which you enter to-night centres around the study of that mysterious condition, *life*, as shown in the highest of created things, *man*. The structure of the human frame, the working of its different parts, the changes constituting disease, all form the practical objects of your chosen study.

But man, viewed as an animal, is not a wholly unique creation. He is but one member of a great family, and partakes of the family characteristics. Hence it happens that many features of human anatomy and physiology are unintelligible by themselves, but become pregnant with meaning when understood as the expression of some general type—some family trait of the great brotherhood of living things. There is, then, really, but one science of life, and its general laws must be studied if we would understand the meaning of the facts presented by any single form of living thing. For biology, as this science is called, is in this respect like a figured woven fabric. View the texture as a whole, and in the colors stamped on its face there appears an artistic design. But unravel warp from woof and examine the tints on each separate thread by itself, and you see but meaningless daubs.

I can think, then, of no more fitting subject for a prefatory lecture than to lay before you one of the fundamental questions of biology, sketch for you the evidence bearing on its answer,

and present you with the result. Thus you will learn a lesson in the method of investigation in natural science, and at the same time become practically acquainted with facts which it is important you should know, as lying at the foundation of anatomy, physiology, and pathology.

The ultimate aim of biology is to know what *is* life; how are its phenomena produced, and what is the true history of life-display on earth. The answers to these questions, if found at all, will be got only from a faithful study of nature. And the first step in the problem is—what ?

Suppose an arithmetician is set the task of extracting the square root of a given number. If it be a whole number, he proceeds at once to the operation. But if instead it be a string of mixed numbers and fractions, he must, as a preliminary step, find a single expression for their sum. This he does by reducing all the terms to simple fractions, aud all these to a common denominator. Adding, then, the now similar terms, he obtains a single fraction that is the equivalent of the whole, and upon this he operates as upon an original simple number.

So is it with the biologist. His problem is to extract the square root of life, not of one living form, but of the whole vast array of animals and plants in all their endless variety. He therefore has the same preliminary step to take as the arithmetician: to reduce all diversity of form and faculty of living things to a similar mode of expression—to find, in short, the common denominator of life.

And this problem is our theme to-night. Weigh well now its full import—its far-reaching scope. For it means no less than a daring search for a single substance as the material basis of all living forms: a single mode of performance of the several vital functions, and a single underlying general plan in the varied architecture of the animate world. And all this, too, not merely between allied forms, as dog and wolf, fir and pine-tree, but between all things whatever that live, animal and vegetable together; between man and the giant forest tree, and between both and the living specks that form the scum on a puddle of ditch-water.

Yet, wild and improbable as seems the idea, it is the proud

boast of the biologist to say to-day, it is realized: this community does exist; after two centuries of patient labor a common denominator of life has been found.

Before examining the evidence on which this sweeping statement rests, let us first be sure that we have a correct idea of the nature of the thing with which we deal. Our theme is living creatures—living matter. Now, what do we mean by the word "living?" The only answer we can give, in our ignorance, is this. Of life in the abstract we know nothing: we simply recognize a state of matter in which it is the seat of certain phenomena, and to this state we apply the term living. That is, all we know of life is the signs by which it shows itself. And these signs, or *essential* vital phenomena, that is, such as are common to everything recognized as alive, are as follows: All living things *nourish* themselves, by which we mean that they renew their substance by converting outside material into their own. They also increase in bulk, or *grow*, by the same process. They reproduce their kind, and finally they display some form of what we may call vital activity, varying from mere sluggish movement in the lowest organisms to the complex functions of the human body and mind. Yet diverse as are these acts, they are but different expressions of a single faculty of living matter, power to determine molecular movement among its particles. For it is a well-ascertained fact in physiology that every vital act whatsover, be it motion, secretion, or the lofty exercise of thought and reason, are all accomplished at the expense of physical or chemical change in the living substance; or, as we may express it singly, have all their determining cause in some mode of motion of the particles of living matter. To sum up, then, we mean by living matter such as can nourish, grow, reproduce, and in some additional mode display molecular movement.

We pass now to our main subject, the alleged discovery that throughout all nature there is but one kind of living matter that executes the functions just detailed, and but one general method, severally, of their performance.

Our first step is plainly to get the *type* of this universal matter and method, and since we seek what is the common property

of all living things, it is equally clear that we shall find the purest type in the lowest creature on the scale, where the phenomena of life occur under the simplest form.

Sail out with me then upon the broad Atlantic. Let us heave to where the sea is deepest—where the ocean-bed lies miles below the vessel's keel. We will then cast the lead with a line several thousand fathoms long. It will sink into abysses where the water is ice-cold and motionless—the darkness eternal: yet on its return from those profound depths we shall very likely find both lead and several feet of the line smeared with a slimy ooze which the haul through more than two miles of water has failed to wash off. Repeat the sounding at another spot a hundred miles or more away, and the result will very probably be the same, showing that the deep sea-bed for hundreds of square miles contains as an ingredient of its oozy mud this sticky material. To the naked eye this stuff is a structureless semi-solid slime. Under the microscope it is seen not to be a continuous mass, but a collection of separate irregular bits or clumps and net-works, which, however, are still utterly devoid of structure—are mere shapeless specks of slime.

Yet is this slimy matter alive as we are alive, and the archetype of the basis-substance of all animate beings: these formless flakes living individuals as ourselves, and their simple life-acts an epitome of the vital phenomena of each and everything that lives. In other words, startling as it may seem, here out of the oozy mud of the Atlantic basin we have that pure type of the matter and method of life that we seek.

Let us then carefully study these lowliest of living things. I premise by telling you that there are several genera of these structureless denizens of the sea known to naturalists. The variety just mentioned, *Bathybius*, as it is called, which is found in such vast quantity in the uttermost depths of the ocean, is by far the most interesting and suggestive. But yet it has been less thoroughly studied than other species in the details of its life-history. As I wish therefore to tell you nothing that has not been actually seen, I shall refer in the following descriptions to better known species of the group, found in more accessible localities. As it is convenient also to have names for what we are

talking about, I will tell you that these objects as a class are called the *Monera*, and we may anglicize the name and speak of an individual as a *moner*, as we would say a horse or a dog.

Let us now imagine one of these minute living moners to be in the field of the microscope, lying free in a little of its native sea-water. What do we see? Apparently an irregular spatter of semi-fluid material, colorless and transparent, but containing a great number of minute particles giving it a granular look. Definite shape it has none, other than that it consists of a central mass from which radiate in all directions delicate branching and anastomosing threads. But all is homogeneous:—central portion and branches are one continuous mass. Throughout the whole there is not the slightest sign of structure, of distinct parts or organs; not even a difference in density between the outer and inner layers of substance. The whole appearance is in miniature what might be formed by a spoonful of granular mucilage dropped on a table from a height, and spread out by the force of the fall into a radiating spatter.

As to composition, the mucus-like substance of the moner, tested chemically, is found to be an albuminous matter, and to behave in a peculiar way with certain reagents.

To determine next the vital endowments of the living mass before us, let us take our seat at the microscope and carefully watch it. The first thing that will strike the eye is that the object is in incessant *motion*. Its outline is constantly changing, and the fine mucous threads ceaselessly lengthening, shortening, separating from one another and reuniting, appearing and disappearing on the surface of the central mass. But more remarkable even than this outward change of form is the restless activity of the substance within itself. *Currents* are moving up and down, right and left, throughout both body and branches, their direction indeterminate and frequently changing. The semi-liquid material thus endlessly courses through channels opening within itself, as water flows through water where the Gulf-stream meets the sea.

Here then we have that fundamental life-act, spontaneous movement, plainly performed under our very eyes. And throughout nature there is nothing more marvellous than this

same sight of a formless matter, structureless, naked and free, spontaneously heaving, quivering, and streaming in and through itself, like molten glass stirred by invisible hands. There is a fascination in the sight, too, as in watching the ocean surf break on shore; for here as there we cannot escape a feeling of awe at thus confronting the workings of an intangible energy, self-contained yet equally distributed throughout the moving mass, wasteful yet unconsumable in its ceaseless display. And indeed in the complex movements of the moner we have actually reproduced the phenomena of the ocean, as though the stormy Atlantic had imbued this humblest of its denizens with its own eternal restlessness. The heaving billows, the never-ending internal agitation and intermingling of waters by currents and tides, are all pictured in tiny miniature in the self-imposed turmoil of the living mass before us.

But suppose, while we are watching this wonderful sight, there happens to be wafted against the moner another dweller of the sea,—an object called a *diatom*, a microscopic vegetable organism encased in a delicate shell of flint. Instantly there is method in the hitherto seemingly objectless movements of the moner, and he proceeds forthwith to literally put himself outside of the intruder. No sooner does the diatom touch one of the moner's gelatinous threads than it is held by the stickiness of the mucus-like substance, and at once both this filament and its neighbors begin to thicken by an influx of matter from the main body. At the same time they gradually fuse together until they form a thick continuous layer, which slowly extends itself around the helpless diatom. This envelopment accomplished, the mass retracts, carrying its prey with it, until the latter is drawn down into the central portion of the moner's substance. Here it remains a certain time, but is at length pushed out again by reversal of the process by which it was captured. Yet if we look closely at the diatom now, we shall find that it is only the *shell* that is cast away, the soft contents having been quietly drawn off and retained in the moner's body. Moreover, if we supply young moners plentifully with diatoms we shall see them rapidly gain in bulk from day to day, showing that the matter thus taken into the moner's body becomes in-

sensibly changed there into new living moner-substance. In other words, we have again been witnessing the performance of one of our fundamental vital functions; namely, the combined act of *nourishing* and *growing*.

One other feat and one only, but that a very simple one, will be enacted by our little friend. At some time in his career we shall chance to see a furrow form around his central mass, which, gradually deepening, ends by splitting him in two. What is the result—death? Not at all: on the contrary, the effect is that whereas we before had one moner we now have two: for each of the divided halves soon takes on all the features of a perfect individual. In other species the reproductive act, for such this plainly is, differs a little in detail. The moner draws in his branched network of threads until he becomes a smooth round ball. Over this a thick, tough, transparent envelope forms, and thus enclosed the round mass gradually splits up into a considerable number of smaller ones. Each of these then develops a tail-like appendage: the investing envelope bursts: and the new brood come swarming out like young tadpoles, being driven swiftly about by lashing of their tails. But they do not keep this form long: for the day after they are first set free they already begin to change to the parent type, a change that finally becomes complete. In this species, thus, the parent, instead of dividing into two, splits up into a number of new individuals.

In still other organisms we have two alternating modes of reproduction. After several generations produced by simple division, two individuals meet and actually fuse together. The mass thus formed becomes encysted as in the moner just described, and after a while the envelope bursts and the entire contents flow out as a countless swarm of excessively minute specks, so small that the very highest powers of the microscope are needed to see them at all. These infinitesimal specks can then be watched and actually seen to grow into the likeness of their parent.

Such is the simple life-history of the monera, and now let us sum up what we have learned by its study. We have seen a purely homogeneous substance—a mere structureless mass of

matter, perform under our eyes the great vital functions of movement, nutrition, growth and reproduction. We thus learn the important fact that life does not necessarily require for its display any structure in the individual, but all its essential functions in their simplest manifestation can be equally performed by one homogeneous matter. Thus the structureless moner, the simplest known, is at the same time the simplest conceivable type of a living individual.

Next as to the substance itself, we find it to be a colorless, transparent, viscid, albuminous matter. As regards the manner of performance of the several vital functions, we see *movement* executed indiscriminately by all the particles of the mass: *nutrition* and *growth* effected by the living matter putting itself bodily around the article of food, and then transforming this into its own substance: and *reproduction* accomplished by the body of the parent dividing directly into new individuals or germs.

Such then are the matter and method of life of the monera: and now let us jump at once to the highest of created organisms, the vertebrate animals, among which we ourselves take rank, and see how their complex structure and functions conform to the type we have been studying.

Prick your finger and examine a drop of blood under the microscope. It consists of a colorless fluid, in which float vast numbers of minute bodies. Most of these are the reddish disk-shaped *corpuscles*, as they are called, that give blood its red color. But besides these, though much fewer in number, are rather larger bodies of—mark now the words—a colorless, transparent, granular, semi-liquid and viscid substance. At first these objects appear as mere motionless balls; but if you prevent the drop of blood from evaporating, and keep it artificially warmed to the natural temperature of the body, or, what is far better, if you take a drop of frog's or newt's blood, which does not need warming, you will soon be the witness of a most striking and wonderful exhibition. The motionless sphere awakes as it were from a swoon, and begins to show signs of life. Its particles begin to move upon each other; the round outline is lost, and the body, or *corpuscle*, as it is called, assumes constantly

changing and most fantastic shapes, and moves actively about in the field of the microscope. Now it throws out from its substance a dozen fine gelatinous threads, and holding by their sticky tips to the surface of the glass slide, retracts upon them, using them thus as agents for locomotion. Again, it divides into two portions connected by a long slender filament. These move off in opposite directions and writhe about independently, until apparently tired of being Siamese twins, they approach each other, while the connecting thread shortens and thickens, and finally meeting, fuse once more into a single mass. If the corpuscle meet a large object, it spreads out into a thin flat layer and creeps over it in that form. If it come upon a narrow channel, such as is often left between masses of red corpuscles, it squeezes through like sand in an hour-glass. In fact there is no end to the protean changes of form that this extraordinary little organism can assume.

Next perform the following experiment:—Take your drop of frog's blood and add to it a little of a fine insoluble powder, as indigo or charcoal, and you will soon see some of these same white blood-corpuscles with one or more grains of the powder embedded in their substance. Moreover, they have been seen with broken fragments of their companion red corpuscles similarly embedded.

Again, warm slightly the slide holding your drop of frog's blood. The movements described become more active, and if you combine good fortune with patience you may see furrows form, disappear and reform on the surface of a corpuscle, until at last one extends completely through, and the little body is split in two. Each half then moves about actively and presents all the features of a perfect individual.

Finally, test these bodies chemically, and you get an albuminous substance reacting precisely like that of the monera.

Now, in this sketch I need not dilate on the points of resemblance between these little corpuscles of the blood and the monera. They are startlingly self-evident. Both are composed of the same kind of substance, have the same physical character, and perform identical vital acts in a generally similar manner. There is, however, one point of difference between the

two. The substance of the moner is perfectly homogeneous, but embedded in that of the white blood-corpuscle are one or more small roundish bodies with well-marked outline. These we call *nuclei*, but of their function and vital significance we know nothing.

We find, then, as the first result of our study of vertebrates, that in their blood, and I may add in the lymph also and several of the tissues, there occur independent freely moving organisms, closely resembling the monera in all important particulars.

But yet these corpuscles we have been describing form a very small part of the bulk of vertebrate animals. What of the *solid* tissues? How do *they* conform to the moner-type of life? Cut out the cornea from the eye of a living or freshly-killed frog and examine it immersed in aqueous humor under the microscope. At first the tissue is perfectly transparent and homogeneous; but after awhile there makes its appearance a network of oval nucleated masses with long slender branching arms or processes—the whole composed of a finely granular but colorless and transparent substance. No further words are needed to call up our humble friend the moner vividly before our eyes. For were it not for the large nucleus, these present bodies, with their soft granular substance and delicate threadlike processes, could easily be imagined to be moners that had crawled into the cornea while the frog was asleep, so close is the outward likeness. Chemistry, too, could be called upon to support the fancy, for once more reagents show in the transparent matter of these corneal corpuscles, as we call them, the albuminous substance of the monera. You will naturally, then, if you are enthusiastic, keep your seat at the microscope and confidently watch for vital movements and reproductive activity on the part of these bodies. But, alas! you will be wofully disappointed. You may watch till your eyes ache with weariness, or till the tissue decomposes, but these pseudo-moners embedded in the substance of the cornea are as motionless as statues. Not a sign of any movement or division for reproduction will occur. But be not too easily thrown off the scent. Remember the important fact, that in the adult the fixed tissues are fully formed.

Active movement, growth, and multiplication of adult anatomical elements could therefore hardly be expected to take place, and it would be illogical to deny these elements functional power merely because they do not constantly exercise it. How, then, shall we decide upon the vital endowments of these corpuscles of the cornea?

You all know of the process called inflammation, and those of you at least who have been here before will call to mind that it in part consists in unusual formative activity, whereby actual organization and growth of new tissue may result at the inflamed spot. Let us then excite in a frog's cornea this abnormal activity; that is, inflame it, and see what picture the microscope will yield. Take a living frog and cauterize the centre of the cornea with a pointed stick of nitrate of silver, and after a few hours remove the part and examine as before. Nothing is more convincing than the picture now seen. The inflammation set on foot by the cautery has aroused a sleeping energy in those hitherto motionless corpuscles, and once more we have the old story repeated. Slow but distinct movement can be seen agitating the granular masses; they have drawn in their processes; have changed their form, and in many cases, if we have waited long enough after the cauterization before removing the cornea, we will find a group of smaller new bodies within the boundary of what was before a single one. In other words, in these fixed anatomical elements of the cornea we have again an example of masses of living substance, which physically, chemically, and vitally conform to the type of the monera. And to make a long story short, in other tissues of the body, as bone, cartilage, glands, epithelium, gray nerve substance, we have, as here in the cornea, nucleated masses of a soft albuminous material forming a prominent element of their structure.

But still our task is not done: these albuminous bodies or corpuscles, as we may for the present call them, form still but a small proportion of the bulk of most of the tissues. Bundles of fine fibres in the cornea, a dense, apparently homogeneous matrix in cartilage or bone, really compose the mass of the tissue, forming a solid substratum in which the

soft corpuscles lie embedded; while in muscle and nerve fibres we have elaborate and special structures with but insignificant traces of any corpuscular elements. Now what of these fibres and matrix substances—these formed elements of tissue? They present none of the physical, chemical, or vital properties of the moner-type; does this type then wholly fail in their life-history? The answer depends on which of the following possibilities is true. Either the formed elements are genetically distinct from the moner-like albuminous bodies associated with them in the tissue, or one has been formed out of and by the other. To settle the question, compare first a tissue, such as cartilage, from an adult and an embryo of the same animal. At once you will be struck by the following fact. In the adult the nucleated albuminous corpuscles are rather sparsely scattered through an abundant firm matrix: but in the embryo precisely the reverse obtains; the corpuscles compose almost the whole bulk of the tissue, lying closely packed, while the matrix substance is small in amount and rudimentary in character, consisting only of a thin shell of matrix-matter on the surface of each corpuscle. The interpretation of this fact is obvious, but let us without more ado go to the bottom of the matter and trace the general plan of tissue-development from the beginning. All animals, as you know, grow from *ova* or eggs, as plants from seeds. Now what is the egg of a vertebrate animal? You will weary of the words when I tell you that in the beginning it is nothing but a soft, granular, transparent, albuminous mass, containing a nucleus, and capable, as seen in some animals, of performing moner-like movement and change of form. Later in its career it becomes surrounded by or interpenetrated with nutrient material for its future use, and is encased in protecting envelopes. When impregnated and about to develop, the nucleus disappears, and the future animal is then, like the monera, but a homogeneous mass of albuminous matter. Next what? Put freshly spawned frog's eggs under the microscope and watch them continuously. After a few hours you will see sluggish movements of the egg-substance within its investing membrane. Then notches develop on its surface, which at

first come and go, but soon become permanent and pass into well-marked furrows. These extend and deepen, and at last, cutting entirely through, divide the egg-mass into several segments. These segments in turn divide, and by continuance of the process what was originally a single mass of living matter is now broken up into a great number of similar but smaller ones.

During this process of division, *nuclei* reappear in the newly formed products of segmentation, so that the embryo now consists of an aggregation of nucleated masses of albuminous matter. But as this multiplication continues a differentiation begins; the successive generations of nucleated bodies arrange themselves into distinct layers, vary in shape, and propagate in such directions that *form* is given to the growing embryo. Still later, indications of the special structures of the adult tissues begin to show themselves, and now, by comparing embryos of different ages, the secret of tissue-building is revealed. In some the nucleated products of segmentation are transformed bodily into the peculiar structures of the tissue, as in muscle, where a single such nucleated body can be seen in all stages of gradual metamorphosis into a muscular fibre. In others the original nucleated masses persist as such, and the special tissue results from the formation around these bodies—and therefore by fair inference through their agency—of new material. Thus in cartilage we have successive shells of cartilage-matter forming around each original segmentation-mass of the embryo tissue, each new layer always forming within the old, until by firm cohesion of these shells there results the apparently homogeneous matrix of adult cartilage with its enclosed soft nucleated corpuscles.

We see thus that in the beginning the entire animal is but a moner-like mass of living albuminous matter; that all the similar masses in the adult tissues are lineal descendants in unbroken series from this parent, and that it is out of or by the agency of these products of segmentation of the original egg-substance that all the complex structures of the adult tissues are formed.

It remains only to inquire into the functional power of these

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same formed tissue-elements, such as muscle, nerve, and connective-tissue fibres, bone and cartilage matrix. We have already seen, by studying the corpuscles of the blood and cornea and the general development of the egg, that the moner-like bodies, or products of segmentation of the egg, possess at some stage of their career, at least, the pre-eminently vital faculties of moving, nourishing, growing, reproducing and forming. Now do the fibres, membranes, and matrix substances of the adult tissues, formed out of or by the action of these nucleated masses, retain the same faculties? You see at once how important is the answer. If it be *no*, it means that the functional power by which we recognize life belongs only to that one albuminous substance found in the monera, the animal egg and its nucleated offspring; while if it be *yes*, it follows that we must at once give up as false all idea of a community of actively living matter throughout nature. Well, the first case is the truth—the answer is universally *no;* whenever living matter departs widely from the type of the soft albuminous material so often described, and becomes differentiated into formed elements of structure, it loses forever the power of independent movement, of growing, reproducing, and forming. Never, in the repair of injuries, in inflammatory processes, or in morbid growths, do the formed anatomical elements take the slightest share in new productions of their own tissue, or show any other changes than degenerative ones. Even in the healthy economy their rôle is purely a passive one. Muscle is passively contractile only; nerve fibres conduct but cannot generate nerve-impulse; bone and cartilage matrix are but dense solid masses to furnish form and stability to the animal structure; and connective-tissue fibrils serve only to hold together adjoining parts. But wherever *active* function is to be performed— wherever the forces of nature are to be turned into life-work, there for the purpose we find collections of moner-substance—the nucleated descendants of the original egg-mass. Thus for secretion there are the glands, whose whole tissue is but an aggregation of such nucleated bodies with only the necessary connective tissue, blood-vessels, and nerves to bring them into relation with the rest of the system. For the

elaboration of nerve-impulse, we have in the great nerve-centres and ganglia, directly connected with the nerve-fibres, soft nucleated corpuscles like those of the cornea, whose subtle molecular movements are the source alike of the power that harmonizes all the actions of the body, and of the still more mysterious operations of the intellect.

I have thus sketched for you, somewhat disjointedly, it is true, the outline of such facts in the physiology of the higher animals as bear upon the problem we are studying, and I must ask you simply to take my word for it that, so far as observation goes, the fundamental principles we have developed hold good throughout the whole animate world—among all grades of animal and vegetable forms.

Let us now simply review the facts we have learned, and state them in abstract form, and we have what is called the *Protoplasm Theory:* a theory which I beg to remind you is in one sense no "theory" at all, inasmuch as it is simply a general statement of fact. We started, you remember, by asserting that the only definition we can give to living matter in general is that it is such as can nourish, grow, reproduce, and display some additional form of functional power reducible to molecular movement. Studying then the lowest and highest of created things, we found, as you will have seen, these somewhat startling facts. The essential vital functions are throughout all nature performed by only one kind of living matter, which is common to all animate forms, and is a homogeneous albuminous substance, of softish consistence, colorless, transparent, and often containing little granules. Wherever found, this living matter presents essentially the same physical aspect, is substantially of the same chemical constitution, and performs the several vital acts after a common general method. We have discovered then what we may fairly call a universal matter of life. Let us give it a name: we do so, and call it *protoplasm*, or primitive forming material.

But here allow me a word to save you from possible confusion of thought. Observe that the term "protoplasm" is applied only to the *living matter as such*, while possessed of the physical and vital characteristics peculiar to its condition:

it is *not* the name of the albuminoid compound or compounds into which chemical analysis can resolve the living mass. The two conceptions are distinct and are to each other as those of diamond and carbon. Diamond is wholly composed of carbon: yet while *carbon* is the chemical element wherever and however occurring, alone or in combination, *diamond* is the distinct thing—the gem-substance as such, characterized by peculiar lustre, transparency, hardness, and planes of cleavage. Disturb the crystalline condition that determines these physical attributes of the mineral, as by heating diamond, protected from the air, between the poles of a powerful battery, and though its chemical composition is unchanged, yet the dull black mass into which the glittering jewel is transformed is, it is needless to say, no longer diamond. In other words, *diamond* is the mineralogist's name for the crystalline gem, and *carbon* the chemical designation of the matter that composes it. So with *protoplasm*: the word belongs not to the chemist as meaning a product of analysis, but to the biologist as the name of a living thing.

To continue our summary, we find next as regards the mode in which protoplasm exists in nature, that it always occurs individualized into small distinct masses, which are generally, but not invariably, nucleated. In the lowest creatures, as the monera, and in the fecundated egg of even the highest organisms, a single such *unit-mass* of protoplasm constitutes the entire individual; while in the higher forms of life, where we have differentiation of parts or true structure, it is by the multiplication of this same unit-mass of the egg and the more or less transformation of its progeny, that all the varied tissues are formed. In other words, throughout all grades of living things the nucleated or non-nucleated mass of protoplasm is the typical anatomical unit of form, as the brick or block of granite is the typical building-unit in masonry. All living organisms may thus be resolved into one or an aggregated number of these elementary units, simple or variously modified and transformed; just as all masonry-work can be considered as a pile of the building elements cemented together and arranged in special manner. Having thus a distinct conception of the unit-mass of protoplasm as the fundamental structural element of life-forms,

let us give it a name. We do so, and call it—I regret to say—a *cell*. Why this name, you will ask: for you perceive at once that it is a complete misnomer: there is nothing whatever "cellular" about a moner or a blood-corpuscle. The name was given when the nature of these protoplasm-masses was misunderstood. From the fact that in some tissues they secrete around themselves a membranous envelope, it was inferred that all did, even where such structures could not be demonstrated. This real or supposed envelope was then considered not only an essential, but the *most* essential feature of the elementary part, and therefore the whole was not unnaturally called a cell. From being in such common use, and being also a short convenient word, the name "cell" has been retained, but I beg you to remember that in its present employment it is only a name, and not a descriptive appellation.

With respect, finally, to the methods by which protoplasm performs the fundamental vital acts, I need not recapitulate what has been so often described already. I will only in this connection point out to you the important fact that *so far as observation has yet gone*—mark the proviso—protoplasm has never been definitely known to arise *de novo*, but is always found derived from pre-existing protoplasm by bodily division of one unit-mass into new individuals or germs.

Such, then, are the pregnant facts that the microscope has revealed, and I leave you to judge whether I was justified in saying at the beginning of the lecture that a common denominator of life had been found. You have seen that throughout the vast domain of the animate world, from man to the monera, there is but one kind of actively living matter—protoplasm: but one mode of its existence, in elementary unit-masses: but one scheme of tissue-building, the multiplication and transformation of such elements: and apparently but one mode of continuance of life on earth, direct division of protoplasm-units into new generations of the same.

Of the significance of these facts and their bearing upon the

great moot questions of science and philosophy, I have no time to speak. That they *are* of deepest import, I need not tell you: it is plain to the most careless thinker. They must enter as a necessary factor into every hypothesis of the origin and mutual relationship of living things, or of the nature of life and the so-called vital force. Even the question of our own proud position among earth's creatures must be argued by the light of the facts concerning protoplasm. For man himself does not escape the community of matter and manner of life that links into one chain all animate forms; and more startling even than our likeness to the ape is the thought that at the beginning of our individual life, as the fecundated egg, we, the highest of created beings, are but a compeer of the lowest: man and moner brother-forms after the same simple type—twin unit-masses of a universal living matter!

But there are yet deeper secrets hidden in nature's bosom than what you have learned to-night: and as one object of my lecture was to illustrate the method of investigation in natural science, I cannot close without a warning word as to some of the requirements of that method, which, unfortunately, are but too often disregarded. The sailor who knows beforehand the position of the harbor he seeks, can by chart and instruments lay his course and sail it with unfailing certainty. But to the hound that hunts the stag through the forest no forecasting of his route is possible. He must be content with the tedious method of striking the trail of his prey, and following blindly all its devious windings. Yet is this faithful tracking of the hound as unerring as the compass of the mariner, for the one will run his game to earth as surely as the other makes his port.

Now we who seek after the great unknown, the secrets of nature, are as the hound in the chase. Like him, we know not where in the forest before us the game lies hid, and our only course is his. We must search for footprints, and having found them, patiently and determinedly follow their leading to the end. To do so, we need keen eyes and clear heads, for the tracks are often faint, and the trail winds and doubles on itself, and is crossed by many an alluring false scent. But above all,

we must, at the outset, abandon every preconceived idea of the position of our chase, and, recking not whither we go, follow faithfully the winding trail, confident that though it may lead through tangled jungles or over dizzy heights, it cannot, in the end, but guide us aright. In Dante we read over the gloomy portal of Hell, "Leave Hope behind all ye who enter here"; but over the beautiful broad face of Nature, there is written on every stone and leaf—murmured by every brook—warbled by every bird, the warning that I bid you heed:—Who cometh here to learn, leave *Prejudice* behind.